US011876426B2

(12) **United States Patent**
Hirata et al.

(10) **Patent No.: US 11,876,426 B2**
(45) **Date of Patent: Jan. 16, 2024**

(54) **HAPTIC ACTUATOR AND VIBRATING MOTOR WITH THROUGH HOLE**

(71) Applicant: **Nidec Corporation**, Kyoto (JP)

(72) Inventors: **Atsunori Hirata**, Kyoto (JP); **Hiroaki Hirano**, Kyoto (JP); **Ryoichi Mitsuhata**, Kyoto (JP)

(73) Assignee: **NIDEC CORPORATION**, Kyoto (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 95 days.

(21) Appl. No.: **17/547,301**

(22) Filed: **Dec. 10, 2021**

(65) **Prior Publication Data**

US 2022/0209638 A1 Jun. 30, 2022

(30) **Foreign Application Priority Data**

Dec. 25, 2020 (JP) 2020-217900

(51) **Int. Cl.**
H02K 33/02 (2006.01)
G06F 3/01 (2006.01)
G06F 3/0354 (2013.01)

(52) **U.S. Cl.**
CPC ***H02K 33/02*** (2013.01); *G06F 3/016* (2013.01); *G06F 3/03545* (2013.01)

(58) **Field of Classification Search**
CPC .. H02K 7/1869; H02K 7/1876; H02K 7/1892; H02K 33/00; H02K 33/02; H02K 33/16; G06F 3/016; G06F 3/03545
USPC .... 310/25, 15, 12.01, 81, 80, 321, 20, 21, 310/28–30, 36–37, 40 MM
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,323,568 B1 * 11/2001 Zabar H02K 33/04 310/12.24
6,326,706 B1 * 12/2001 Zhang F04B 35/045 310/12.32
6,644,943 B1 * 11/2003 Lilie F04B 35/045 417/418
6,737,780 B1 * 5/2004 Fisher H02K 1/17 310/154.14

(Continued)

FOREIGN PATENT DOCUMENTS

JP 08-065990 A 3/1996
JP 2006-183754 A 7/2006

OTHER PUBLICATIONS

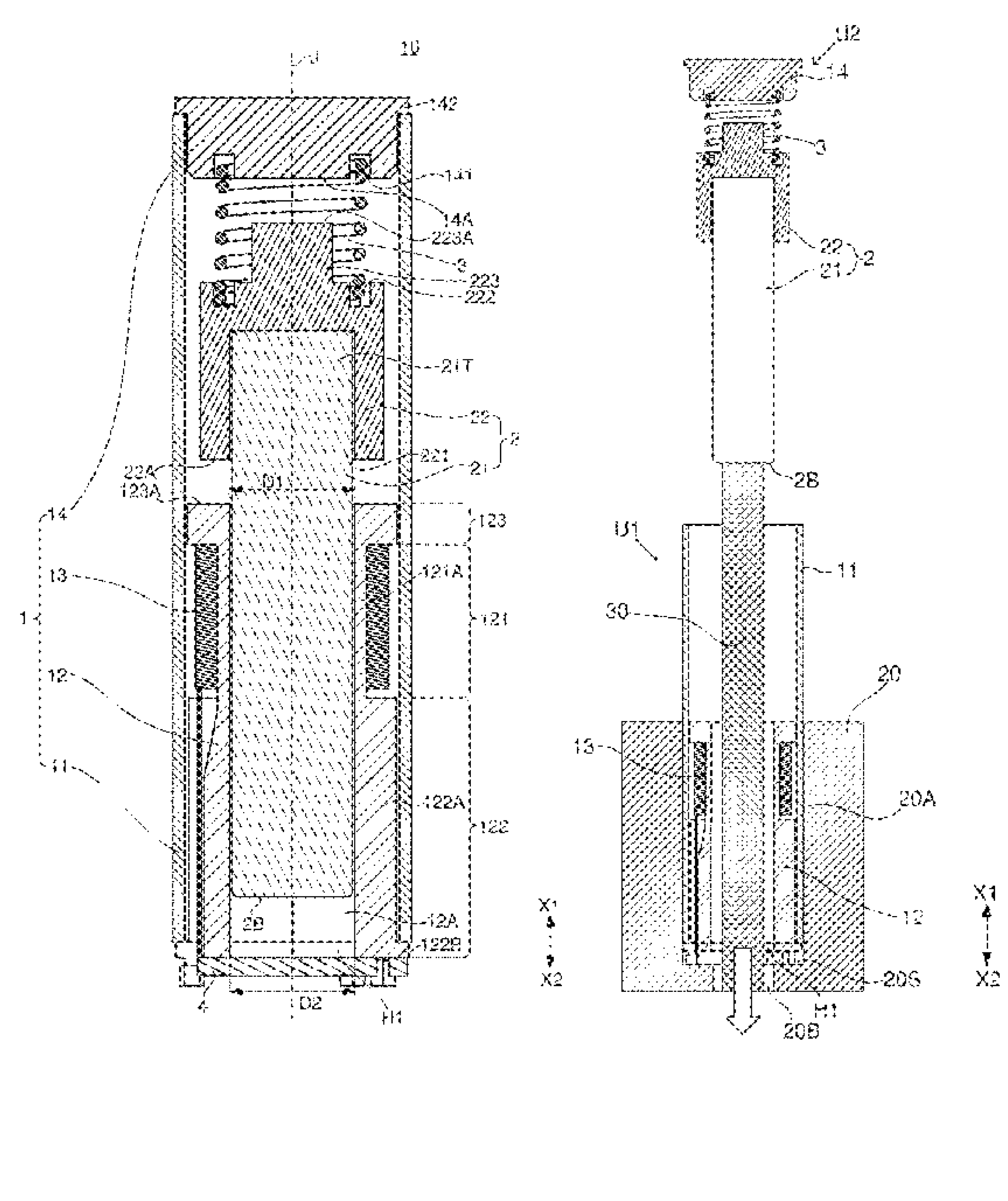
JP2006183754A English Translation (Year: 2006).*

Primary Examiner — Maged M Almawri
(74) *Attorney, Agent, or Firm* — Keating & Bennett, LLP

(57) **ABSTRACT**

A vibrating motor includes a stationary portion, and a movable portion able to vibrate with respect to the stationary portion along a center axis extending in a vertical direction. The stationary portion includes a bearing portion which supports the movable portion to be able to vibrate along the center axis and has a tubular shape extending along the center axis, and a coil which directly or indirectly opposes at least a portion of the movable portion in a radial direction. A lower end portion of the bearing portion has a tubular shape extending along the center axis. A communication hole which penetrates in the vertical direction and allows an outside of the bearing portion and an inside of a portion above the lower end portion of the bearing portion to communicate with each other is provided on a radially inner side of the lower end portion.

11 Claims, 8 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

7,078,832	B2 *	7/2006	Inagaki	H02K 7/14 335/238
7,316,545	B2 *	1/2008	Lenke	F04B 17/046 92/169.1
7,573,163	B2 *	8/2009	Tu	H02K 39/00 310/12.21
7,981,107	B2 *	7/2011	Olsen	A61M 5/14276 604/152
8,314,519	B2 *	11/2012	Eckstein	F16H 25/20 310/12.01
8,368,268	B2 *	2/2013	Hasegawa	G02B 21/248 359/381
8,446,055	B2 *	5/2013	Jun	H02K 33/16 310/23
9,004,883	B2 *	4/2015	Neelakantan	F04B 17/046 417/415
9,906,109	B2 *	2/2018	Endo	H02K 33/16
10,424,429	B2 *	9/2019	Fatemi	H01F 7/1607
10,447,133	B2 *	10/2019	Jin	H02K 33/18
10,547,233	B2 *	1/2020	Jin	H02K 5/04
10,566,888	B2 *	2/2020	Degner	H02K 33/18
10,890,169	B2 *	1/2021	Jeong	F04B 39/0061
11,031,857	B2 *	6/2021	Wasenczuk	H02N 2/186
11,152,843	B2 *	10/2021	Wasenczuk	H02K 1/34
11,309,808	B1 *	4/2022	Li	H02K 35/02
2002/0195884	A1 *	12/2002	Ichii	A61C 17/34 310/15
2004/0119343	A1 *	6/2004	Ueda	G10K 9/18 310/12.31
2004/0128781	A1 *	7/2004	Kunita	H02K 33/08 15/22.2
2004/0241017	A1 *	12/2004	Buzzi	F04B 19/006 417/415
2005/0089418	A1 *	4/2005	Bonfardeci	F04B 17/046 417/417
2009/0051471	A1 *	2/2009	Zhao	H01F 7/1607 335/261
2009/0232666	A1 *	9/2009	Choi	H02K 33/16 417/212
2011/0133577	A1 *	6/2011	Lee	H02K 33/18 310/15
2011/0198949	A1 *	8/2011	Furuich	H02K 33/16 310/25
2011/0316361	A1 *	12/2011	Park	H02K 33/16 310/25
2013/0169071	A1 *	7/2013	Endo	H02K 33/12 310/25
2014/0035397	A1 *	2/2014	Endo	H02K 33/18 310/30
2014/0062225	A1 *	3/2014	Kim	H02K 33/00 310/15
2014/0077628	A1 *	3/2014	Yamada	H02K 33/12 310/12.16
2014/0084710	A1 *	3/2014	Endo	H02K 33/16 310/25
2015/0137628	A1 *	5/2015	Endo	H02K 33/16 310/25
2015/0206639	A1 *	7/2015	Odajima	B06B 1/045 335/235
2016/0094115	A1 *	3/2016	Okawa	A61C 17/3445 310/25
2016/0164389	A1 *	6/2016	Jang	H02K 7/116 310/20
2017/0070131	A1 *	3/2017	Degner	H02K 33/00
2017/0214306	A1 *	7/2017	Katada	H02K 33/16
2018/0056329	A1 *	3/2018	Akanuma	H02K 33/16
2018/0219465	A1 *	8/2018	Katada	B06B 1/045
2018/0250107	A1 *	9/2018	Dai	H02K 1/2791
2019/0044425	A1 *	2/2019	Zu	H02K 33/02
2019/0151895	A1 *	5/2019	Takahashi	H02K 33/18

* cited by examiner

FIG. 1

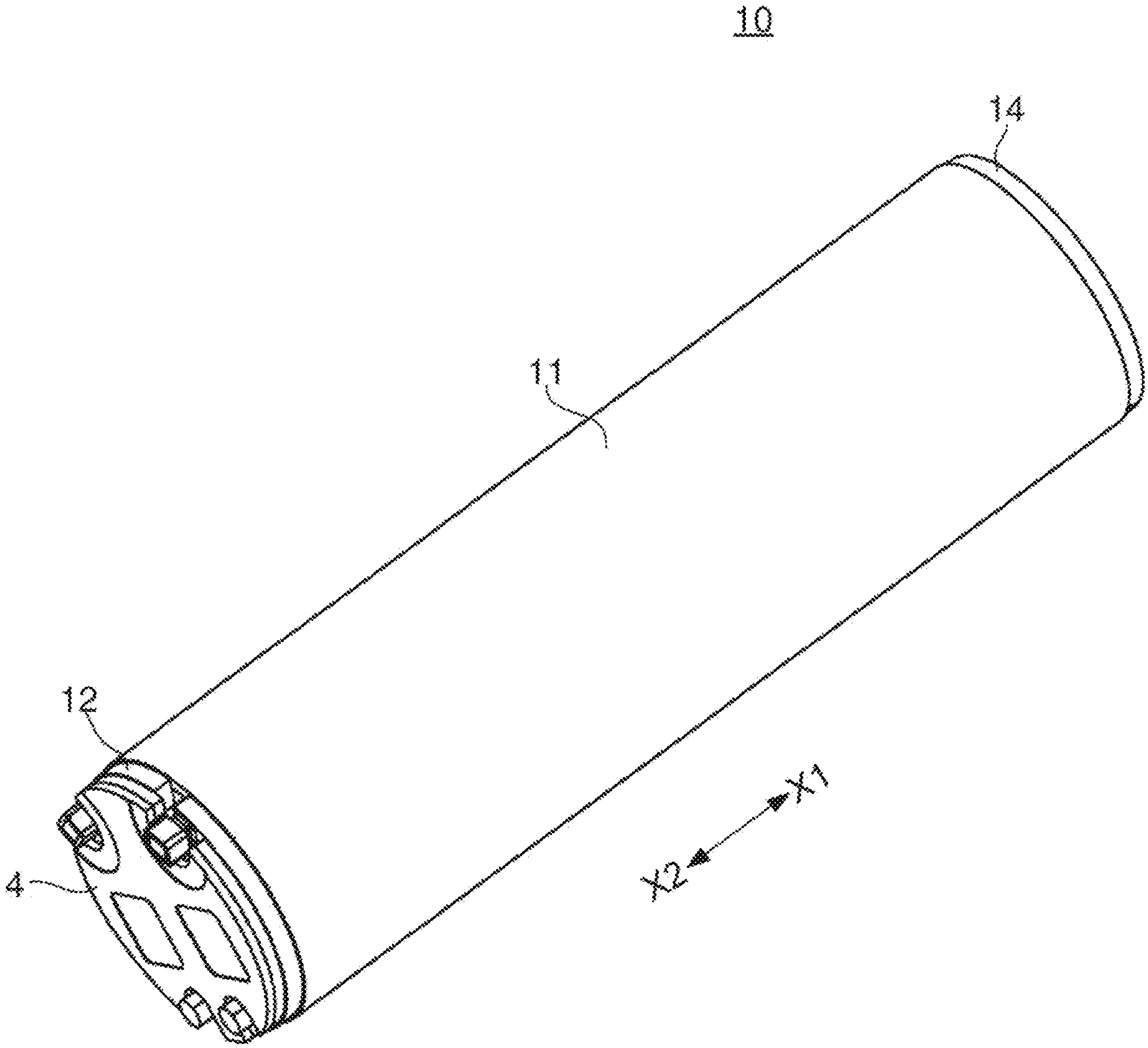


FIG. 2

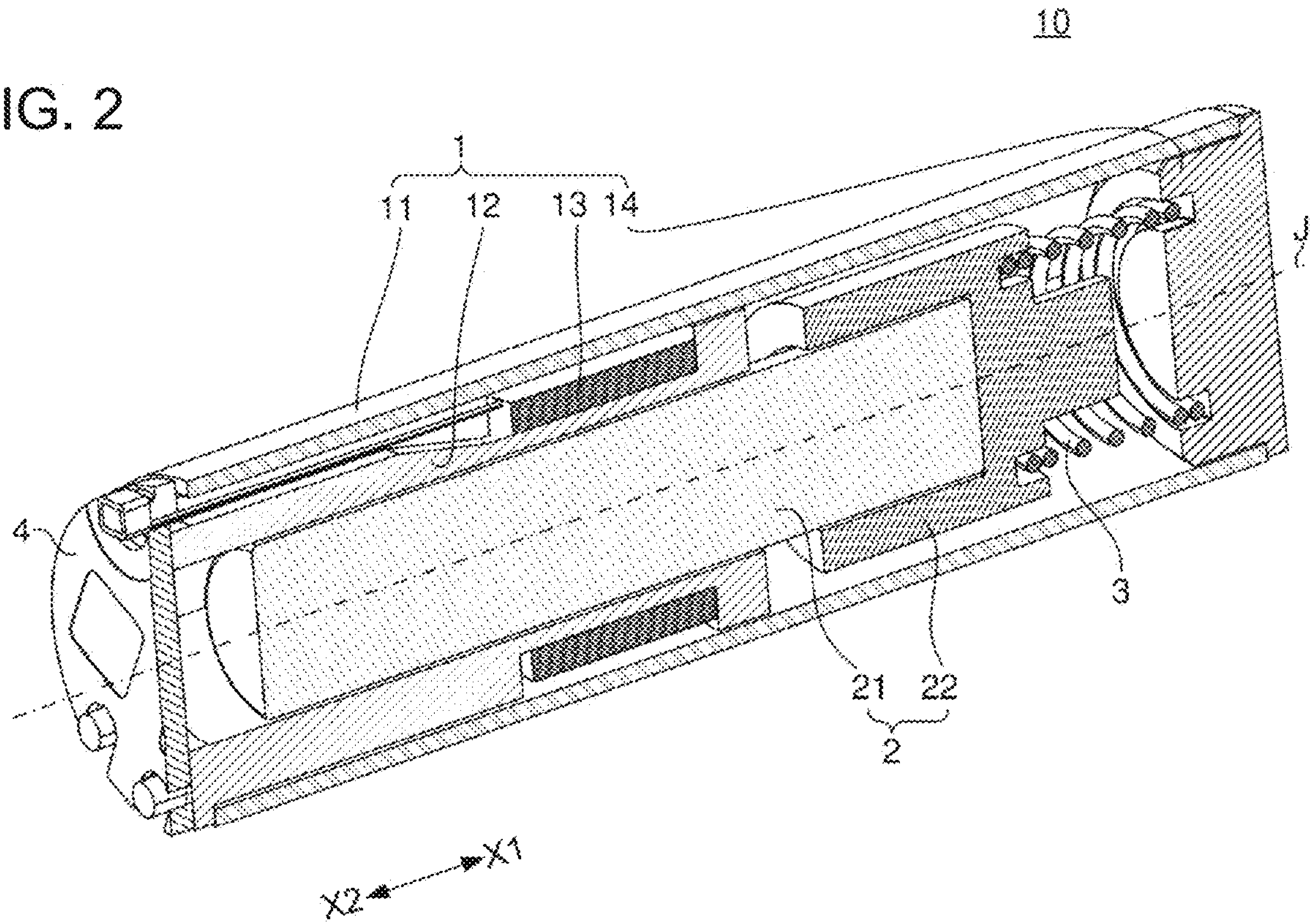


FIG. 3

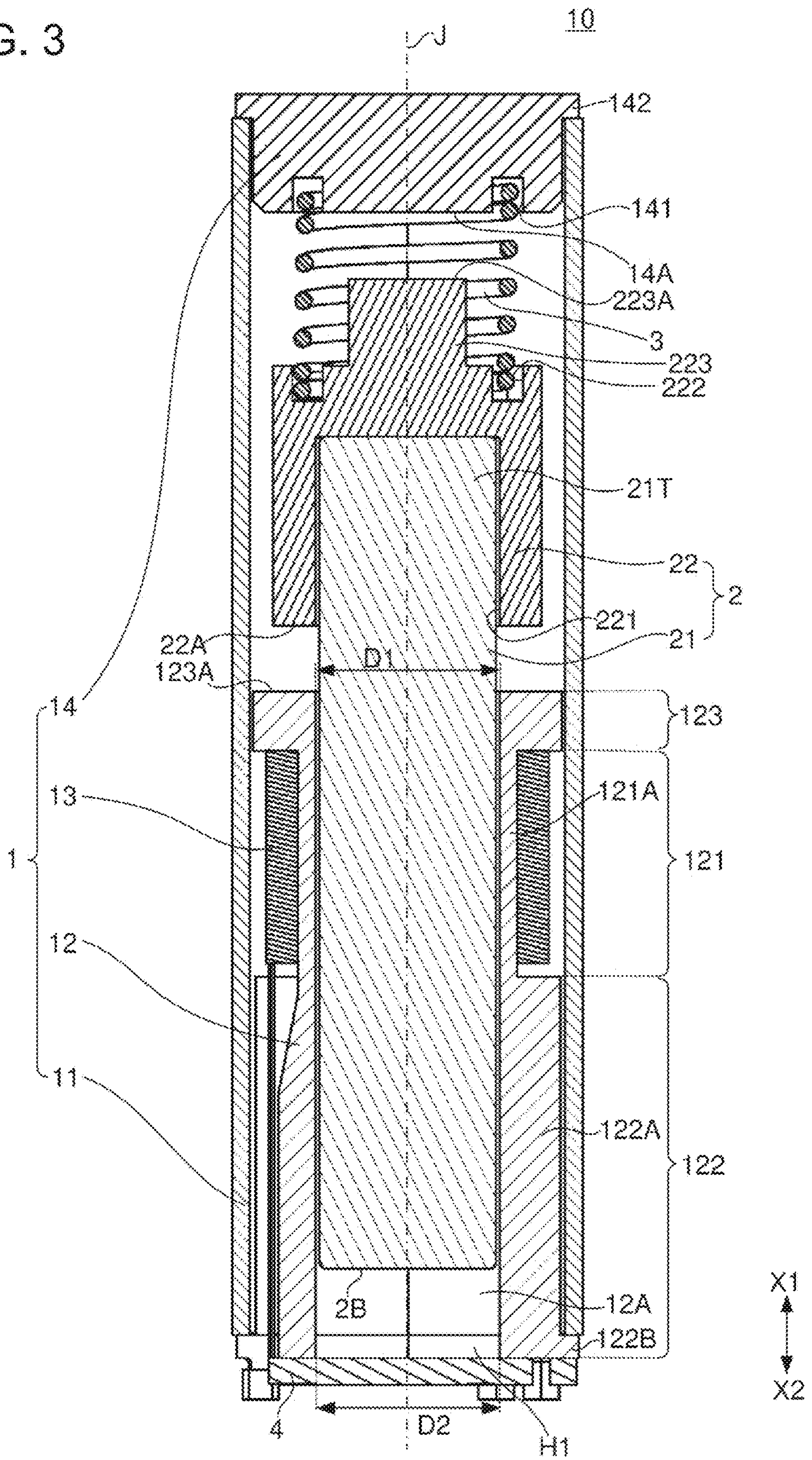

10
J
142
141
14A
223A
3
223
222
21T
22
2
221
21
22A
123A
D1
14
123
13
121A
1
121
12
11
122A
122
12A
2B
122B
X1
X2
4
D2
H1

FIG. 4

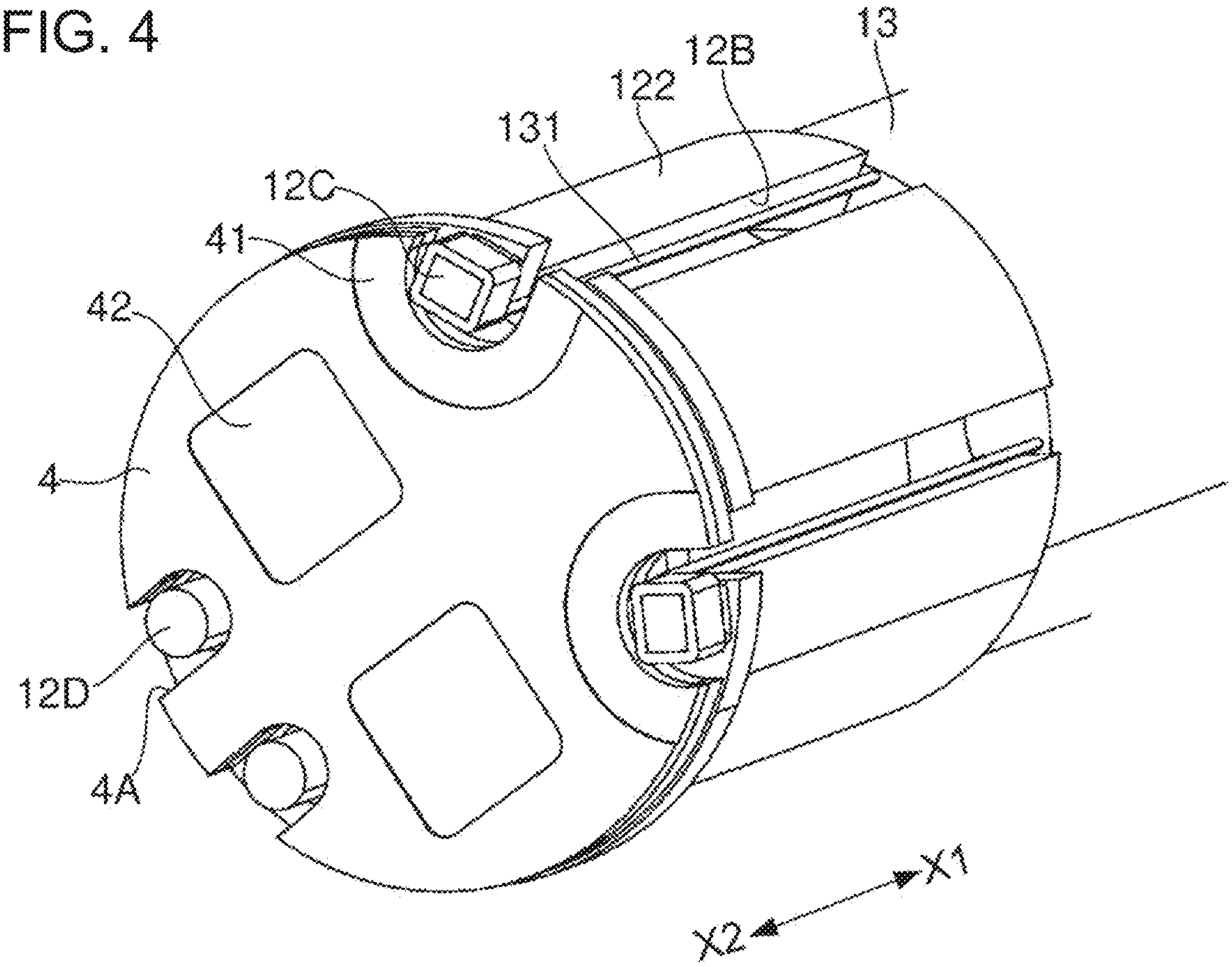


FIG. 5

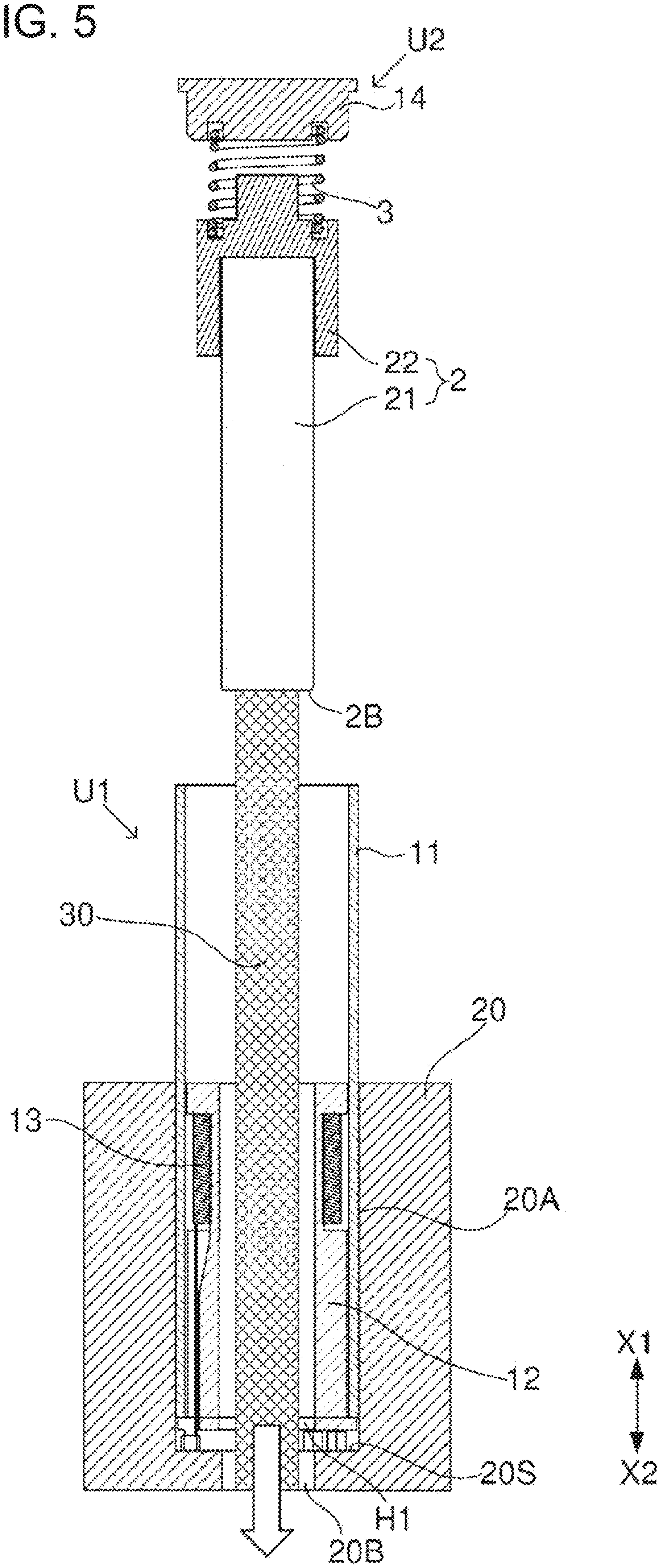


FIG. 6

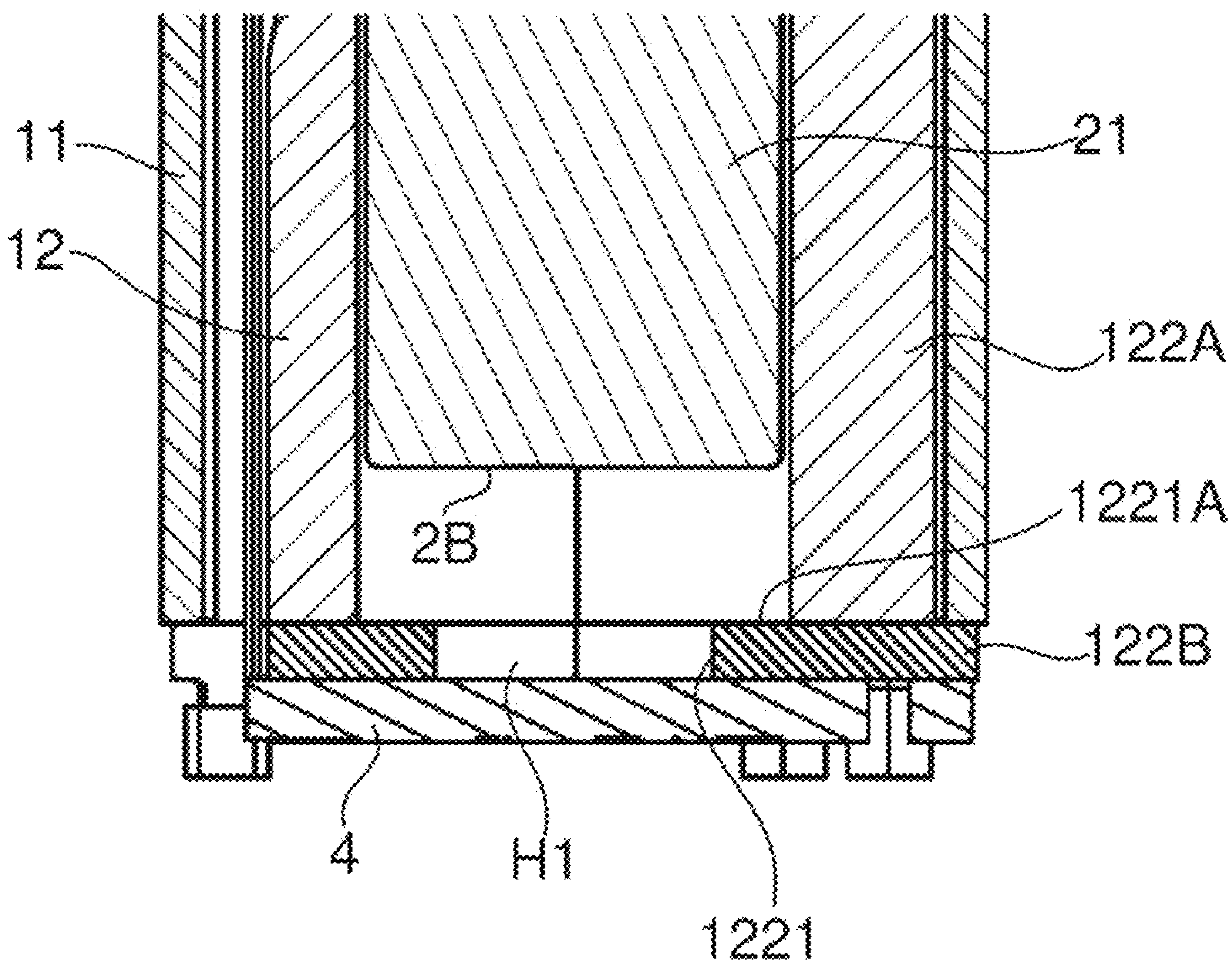


FIG.7

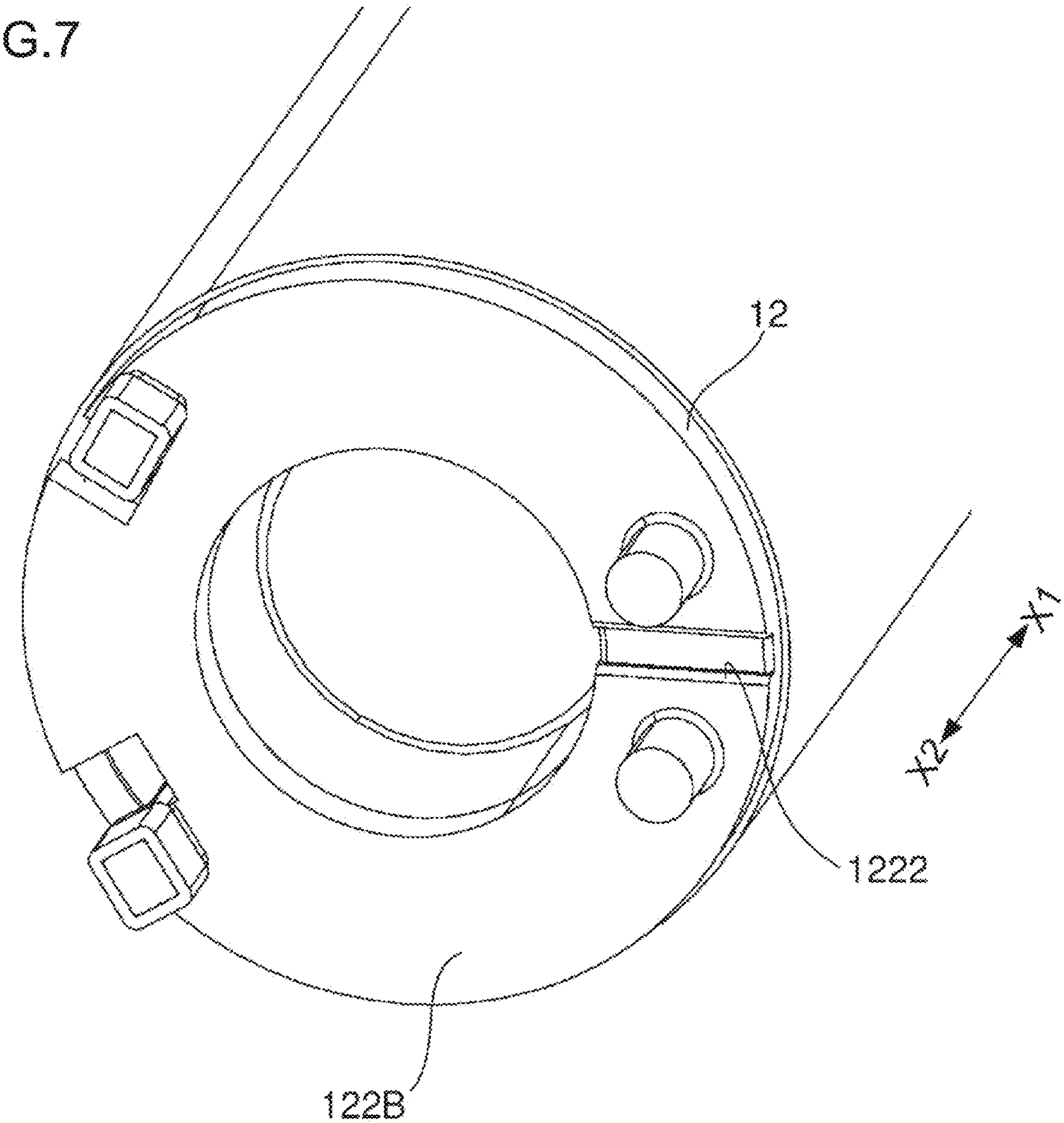
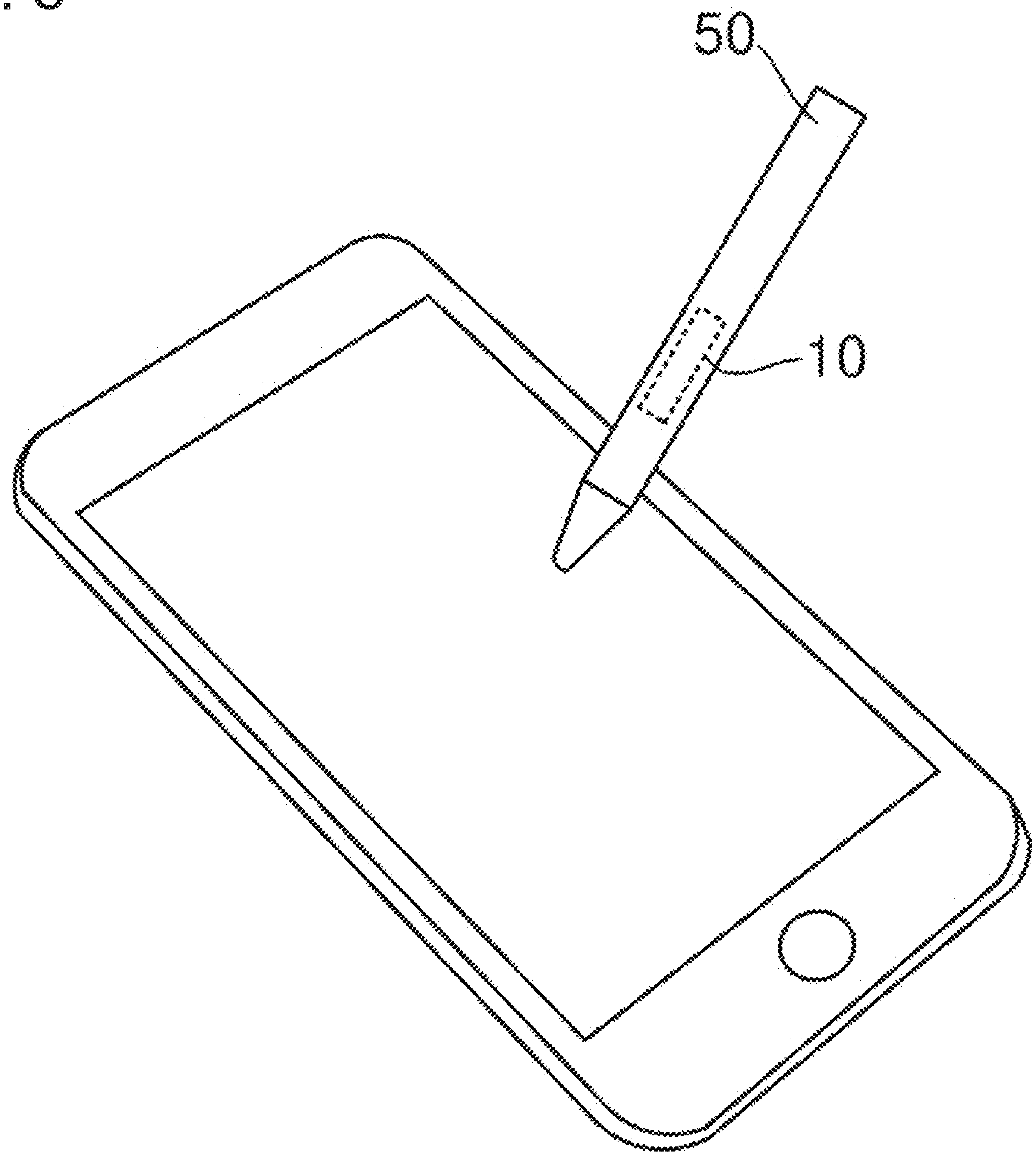


FIG. 8



HAPTIC ACTUATOR AND VIBRATING MOTOR WITH THROUGH HOLE

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority under 35 U.S.C. § 119 to Japanese Patent Application No. 2020-217900, filed on Dec. 25, 2020, the entire contents of which are hereby incorporated herein by reference.

1. FIELD OF THE INVENTION

The present disclosure relates to a vibrating motor and a haptic device.

2. BACKGROUND

Conventionally, various devices such as portable devices like smartphones have been provided with a vibrating motor as a vibration generator. The vibrating motor is used for a function of notifying the user of an incoming call, an alarm, or the like, or a function of haptic feedback in a human interface, for example.

A vibrating motor includes a case, a coil, an elastic portion, and a movable portion. The movable portion includes a magnet. The movable portion and the case are often connected by an elastic portion. When the coil is energized to generate a magnetic field, the movable portion vibrates.

Here, in a case where the movable portion is not supported in the radial direction orthogonal to the vibration direction, there is a possibility that the manufacturing efficiency of the vibrating motor decreases in order to accurately arrange the movable portion in the radial direction.

SUMMARY

An example embodiment of a vibrating motor of the present disclosure includes a stationary portion, and a movable portion able to vibrate with respect to the stationary portion along a center axis extending in a vertical direction. The stationary portion includes a bearing portion which supports the movable portion to be able to vibrate along the center axis and has a tubular shape extending along the center axis, and a coil which directly or indirectly opposes at least a portion of the movable portion in a radial direction. A lower end portion of the bearing portion has a tubular shape extending along the center axis. A communication hole which penetrates in the vertical direction and allows an outside of the bearing portion and an inside of a portion above the lower end portion of the bearing portion to communicate with each other is provided on a radially inner side of the lower end portion. At least a portion of a lower surface of the movable portion overlaps the communication hole in the vertical direction.

The above and other elements, features, steps, characteristics and advantages of the present disclosure will become more apparent from the following detailed description of the example embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a vibrating motor according to an example embodiment of the present disclosure.

FIG. **2** is a longitudinal sectional perspective view of a vibrating motor according to an example embodiment of the present disclosure.

FIG. **3** is a longitudinal sectional view of a vibrating motor according to an example embodiment of the present disclosure.

FIG. **4** is a perspective view illustrating a configuration related to an electrical connection between a board and a coil according to an example embodiment of the present disclosure.

FIG. **5** is a sectional view illustrating a step in a manufacturing process of a vibrating motor according to an example embodiment of the present disclosure.

FIG. **6** is a longitudinal sectional view illustrating a partial configuration of a vibrating motor according to a modification of an example embodiment of the present disclosure.

FIG. **7** is a perspective view illustrating a lower end portion of a bearing portion according to another modification of an example embodiment of the present disclosure.

FIG. **8** is a view schematically illustrating a touch pen mounted with a vibrating motor according to an example embodiment of the present disclosure.

DETAILED DESCRIPTION

Example embodiments of the present disclosure will be described hereinbelow with reference to the drawings.

Incidentally, in the drawings, a direction in which a center axis J of a vibrating motor **10** extends is referred to as a "vertical direction", an upper side is referred to as X**1**, and a lower side is referred to as X**2**. Incidentally, the vertical direction does not limit the attaching direction of the vibrating motor **10** when the vibrating motor **10** is mounted on a device.

A radial direction with respect to the center axis J is simply referred to as a "radial direction", a direction approaching the center axis J is referred to as a radially inward direction, and a direction away from the center axis J is referred to as a radially outward direction.

FIG. **1** is a perspective view of the vibrating motor **10** according to an example embodiment of the present disclosure; FIG. **2** is a longitudinal sectional perspective view of the vibrating motor **10** illustrated in FIG. **1**. FIG. **3** is a longitudinal sectional view of the vibrating motor **10** illustrated in FIG. **1**.

The vibrating motor **10** includes a stationary portion **1** and a movable portion **2**. In this example embodiment, the vibrating motor **10** further includes an elastic portion **3** and a board **4**. The movable portion **2** extends along the center axis J. The movable portion **2** can vibrate with respect to the stationary portion **1** along the center axis J. The center axis J extends in the vertical direction.

The stationary portion **1** includes a bearing portion **12** and a coil **13**. In this example embodiment, the stationary portion **1** further includes a housing **11** and a top surface portion **14**.

The housing **11** is a cylindrical member extending in the vertical direction. Incidentally, the housing **11** is not limited to the cylindrical shape, and may have, for example, a quadrangular tubular shape or the like. That is, it is sufficient if the housing **11** has a tubular shape extending in the vertical direction. The housing **11** is made of a magnetic material. The magnetic material is stainless steel, for example. The housing **11** houses the movable portion **2** and the elastic portion **3**. In this example embodiment, the housing **11** further houses the bearing portion **12** to be described later.

The bearing portion **12** is a tubular sleeve bearing extending along the center axis J. The bearing portion **12** is made of, for example, a resin having a low friction coefficient and a low wear property. The resin is, for example, polyacetal (POM).

The bearing portion **12** has a hollow portion **12**A extending in the vertical direction. The bearing portion **12** includes a first region **121**, a second region **122**, and a third region **123**. The second region **122** is arranged below the first region **121**. The third region **123** is arranged above the first region **121**.

The first region **121**, the second region **122**, and the third region **123** are integrally formed. That is, the bearing portion **12** is formed by integral molding. In the configuration illustrated in FIG. **3**, an inner diameter D**1** at the upper end of the bearing portion **12** is smaller than an inner diameter D**2** at the lower end of the bearing portion **12**. The inner diameter D**1** is slightly smaller than the inner diameter D**2**. As a result, it becomes easy to remove a mold downward at the time of manufacturing the bearing portion **12** by integral molding. Further, when the movable portion **2** vibrates in the vertical direction, the region close to the center of the movable portion **2** in the vertical direction is supported by the upper end of the bearing portion **12**, so that the movable portion **2** can be suppressed from swinging in the radial direction from the center axis J, and thus the vibration of the movable portion **2** is stabilized.

More specifically, the inner diameter of the bearing portion **12** continuously increases from the inner diameter D**1** toward the inner diameter D**2**. In FIG. **3**, the outer edge of the hollow portion **12**A is linearly inclined downward and radially outward. That is, the inner diameter of the bearing portion **12** continuously increases toward the lower side. As a result, the manufacturing of a mold for manufacturing the bearing portion **12** is facilitated.

Incidentally, for example, a plurality of regions having a constant inner diameter in the vertical direction may be arranged in the vertical direction from the inner diameter D**1** to the inner diameter D**2**, and the inner diameter may be discontinuously increased toward the lower side. This also makes it easy to remove the mold downward.

The first region **121** has a cylindrical shape extending in the vertical direction. A conductive wire is wound around the radially outer periphery of the first region **121** to form the coil **13**. The coil **13** is formed by winding a conductive wire around the center axis J. The radially inner surface of the coil **13** is in contact with the radially outer surface of the first region **121**. That is, the first region **121** includes a coil inner region **121**A arranged on the radially inner side of the coil **13**.

The radially outer end position of the first region **121** coincides with the radially inner end position of the coil **13**. As a result, at the time of manufacturing the vibrating motor **10**, the coil **13** can be wound around the first region **121** after the bearing portion **12** is formed, and thus the manufacturing cost can be reduced.

The second region **122** includes a cylindrical bearing cylinder portion **122**A extending in the vertical direction and a lower end portion **122**B arranged below the bearing cylinder portion **122**A. That is, the bearing portion **12** includes the bearing cylinder portion **122**A. The bearing cylinder portion **122**A has a tubular shape extending in the vertical direction. The bearing portion **12** has the lower end portion **122**B. The lower end portion **122**B has a tubular shape extending along the center axis J. More specifically, the lower end portion **122**B has a cylindrical shape. The radially outer end of the lower end portion **122**B is arranged on the radially outer side relative to the radially outer end of the bearing cylinder portion **122**A. At the time of manufacturing the vibrating motor **10**, the bearing portion **12** is inserted into the housing **11** from below. By the insertion, the upper surface at the radially outer end portion of the lower end portion **122**B comes into contact with the lower surface of the housing **11** in the vertical direction. As a result, the bearing portion **12** can be positioned with respect to the housing **11** in the vertical direction.

A space surrounded by the radially inner surface of the lower end portion **122**B is a communication hole H**1**. The communication hole H**1** corresponds to a lower end portion of the hollow portion **12**A. That is, the communication hole H**1** which penetrates in the vertical direction and allows the outside of the bearing portion **12** and the inside of a portion of the bearing portion **12** above the lower end portion **122**B to communicate with each other is provided on the radially inner side of the lower end portion **122**B. The reason for providing the communication hole H**1** will be described later.

At the boundary between the lower end portion **122**B and the upper portion of the bearing portion **12** above the lower end portion **122**B, the inner diameter of the lower end portion **122**B (the outer diameter of the communication hole H**1**) and the inner diameter of the upper portion are the same. That is, the outer diameter of the movable portion **2**, the inner diameter of the bearing portion **12**, and the inner diameter of the lower end portion **122**B of the bearing portion **12** configuring the communication hole H**1** are substantially the same. As a result, the bearing portion **12** including the lower end portion **122**B can be integrally molded.

In a state where the bearing portion **12** is housed in the housing **11**, the housing **11** is arranged on the radially outer side relative to the radially outer end of the coil **13**.

The radially outer surface of the bearing cylinder portion **122**A is arranged on the radially outer side relative to the radially outer surface of the coil **13**. That is, the radially outer surface of the second region **122** is arranged on the radially outer side relative to the radially outer surface of the first region **121**. The upper surface of the second region **122** is arranged to face the lower end of the coil **13** in the vertical direction. As a result, the coil **13** can be suppressed from moving downward from the upper surface of the second region **122**.

The third region **123** has a cylindrical shape extending in the vertical direction. The radially outer end of the third region **123** is arranged on the radially outer side relative to the radially inner end of the coil **13**. The lower surface of the third region **123** is arranged to face the upper end of the coil **13** in the vertical direction. The third region **123** is a flange portion. As a result, the coil **13** can be suppressed from moving upward from the lower surface of the third region **123**.

The movable portion **2** includes a core portion **21** and a holding portion **22**.

The core portion **21** is a columnar member extending along the axial direction. In this example embodiment, the core portion **21** includes, for example, two magnets arranged in the vertical direction, and a magnetic body vertically sandwiched by the magnets. In this case, for example, the lower side of the upper magnet is the N pole, and the upper side is the S pole. The upper side of the lower magnet is the N pole, and the lower side is the S pole. That is, the N poles face each other in the vertical direction with the magnetic body interposed therebetween. When the housing **11** is made of a magnetic material, it is possible to suppress leakage of the magnetic field generated by the magnet and the coil **13** to the outside of the vibrating motor **10** and to increase a magnetic force. Incidentally, the magnetic pole of each magnet may be opposite to the above in the vertical direction.

The holding portion **22** holds an upper end portion **21**T of the core portion **21**. The holding portion **22** has a columnar recess **221** recessed upward in a columnar shape. The upper end portion **21**T is arranged in the columnar recess **221**. The upper end portion **21**T is fixed to the columnar recess **221** by, for example, adhesion. That is, the holding portion **22** is fixed to the core portion **21**.

The holding portion **22** functions as a weight and is made of metal, for example. An example of the metal is a tungsten alloy.

The holding portion **22** has an annular recess **222** recessed downward in an annular shape from the upper surface. The lower end portion of the elastic portion **3** is fixed to the annular recess **222**. The elastic portion **3** is fixed to the annular recess **222** by welding or adhesion, for example. That is, the elastic portion **3** is arranged above the movable portion **2**. An upper end portion of the movable portion **2** is fixed to a lower end portion of the elastic portion **3**.

The top surface portion **14** is a substantially disk-shaped lid member centered on the center axis J. The top surface portion **14** has an annular recess **141** which is annularly recessed upward from the lower surface. The upper end portion of the elastic portion **3** is fixed to the annular recess **141**. The elastic portion **3** is fixed to the annular recess **141** by welding or adhesion, for example. That is, the top surface portion **14** is fixed to the upper end portion of the elastic portion **3**.

The top surface portion **14** has a top surface flange portion **142** protruding in the radial direction. At the time of manufacturing the vibrating motor **10**, the top surface portion **14** is inserted into the housing **11** from above. At this time, the lower surface of the top surface flange portion **142** is in contact with the upper surface of the housing **11** in the vertical direction. As a result, the top surface portion **14** can be positioned in the vertical direction with respect to the housing **11**, and the strength of the vibrating motor **10** can be improved. The top surface portion **14** is fixed to the upper end portion of the housing **11**.

With such a configuration, the movable portion **2** is supported by the top surface portion **14** with the elastic portion **3** interposed therebetween. In a state where the elastic portion **3** has a natural length, as illustrated in FIG. **3**, a lower part of the core portion **21** is housed in the hollow portion **12**A of the bearing portion **12**. As a result, the core portion **21** is supported by the bearing portion **12** so as to be able to vibrate along the center axis J. That is, the bearing portion **12** supports the movable portion **2** so as to be able to vibrate along the center axis J. That is, the bearing portion **12** supports the movable portion **2** so as to be able to vibrate along the center axis J, and has a tubular shape extending along the center axis J. More specifically, the core portion **21** partially faces the third region **123**, the first region **121**, and the bearing cylinder portion **122**A in the radial direction on the radially inner side of the third region **123**, the first region **121**, and the bearing cylinder portion **122**A, respectively. That is, the bearing cylinder portion **122**A is arranged to face the movable portion **2** in the radial direction. That is, the bearing portion **12** extends along the center axis J and supports the movable portion **2** so as to be able to vibrate along the center axis J. Further, the radially outer surface on the lower side of the movable portion **2** is supported by the bearing portion **12**, but the lower side of the movable portion **2** is not supported in the axial direction. As a result, as compared with a case where the movable portion is supported by an elastic portion or the like from both sides of the vertical direction, it is possible to suppress the restoring force of the movable portion in the vertical direction from becoming larger than necessary. Therefore, the vibration of the movable portion in the vertical direction can be increased. Further, since it is not necessary to arrange the elastic portion below the movable portion **2**, the configuration of the vibrating motor **10** is simplified, and mass productivity is improved.

The stationary portion **1** includes the coil **13**. In a state where the elastic portion **3** has a natural length, as illustrated in FIG. **3**, a part of the core portion **21** faces the coil **13** in the radial direction with the coil inner region **121**A interposed therebetween. That is, the coil **13** indirectly faces at least a part of the movable portion **2** in the radial direction. Incidentally, the bearing portion may be provided below the coil, and the coil may directly face at least a part of the movable portion in the radial direction.

When the coil **13** is energized, a magnetic field is generated from the coil **13**. The movable portion **2** vibrates in the vertical direction by the interaction between the generated magnetic field and the magnetic field by the core portion **21**.

Since the first region **121** includes the coil inner region **121**A, the movable portion **2** and the coil **13** can be separated by the coil inner region **121**A. As a result, the radial thickness of the coil inner region **121**A can be reduced, and the vibrating motor **10** can be downsized in the radial direction.

The second region **122** is arranged below the lower end of the coil **13**. Therefore, by providing the bearing portion **12** with the second region **122** in addition to the first region **121**, the vertical length of the inner surface of the bearing portion **12** radially facing the movable portion **2** is increased, and the inclination of the movable portion **2** during vibration can be suppressed. As a result, the vibration can be stabilized.

As illustrated in FIG. **3**, in a state where the elastic portion **3** has a natural length, a part of the movable portion **2** is arranged on the radially inner side of each of the radially inner surface of the first region **121** and the radially inner surface of the second region **122**. As a result, the vertical length of the movable portion **2** radially facing the inner surface of the bearing portion **12** is increased, and the inclination of the movable portion **2** at the time of vibration can be suppressed. Therefore, the vibration of the movable portion **2** is stabilized. Incidentally, in a state where the elastic portion **3** has a natural length, a part of the movable portion **2** may not be positioned on the radially inner side of the second region **122**.

The bearing portion **12** has the third region **123** arranged above the first region **121**. As a result, the vertical length of the inner surface of the bearing portion **12** radially facing the movable portion **2** is increased, and the inclination of the movable portion **2** at the time of vibration can be further suppressed. Incidentally, the radially outer end of the third region **123** may be arranged on the radially inner side relative to the radially inner end of the coil **13**.

A lower surface **22**A of the holding portion **22** is arranged to directly face an upper surface **123**A of the third region **123** in the vertical direction. That is, the movable portion **2** has the surface **22**A which is arranged to directly face the upper surface **123**A of the third region **123** in the vertical direction. As a result, the surface **22**A of the movable portion **2** can come into contact with the upper surface **123**A of the third region **123**, and the downward movement of the movable portion **2** can be restricted. In particular, the downward movement of the movable portion **2** is restricted as described above, so that the movable portion **2** can be suppressed from coming out below the second region **122**. Further, as will be described later, when the board **4** is arranged below the second region **122**, the movable portion **2** can be suppressed from coming into contact with the board **4**.

As illustrated in FIG. **3**, the holding portion **22** has a protruding portion **223** protruding upward. The protruding portion **223**, that is, the upper surface **223**A of the holding portion **22** is arranged to directly face the lower surface **14**A of the top surface portion **14** in the vertical direction. As a result, the upper surface **223**A of the holding portion **22** can come into contact with the lower surface **14**A of the top surface portion **14**, and the upward movement of the movable portion **2** can be restricted.

FIG. **4** is a perspective view illustrating a configuration related to electrical connection between the board **4** and the coil **13**. As illustrated in FIG. **4**, a recess **12**B extending in the vertical direction and recessed radially inward is formed on the radially outer surface of the second region **122** in the bearing portion **12**. A part of the lead wire **131** drawn out from the coil **13** is housed in the recess **12**B. Incidentally, the entire lead wire **131** may be housed in the recess **12**B. That is, it is sufficient if at least a part of the lead wire **131** is housed in the recess **12**.

As a result, it is not necessary to route the lead wire **131** radially outward of the bearing portion **12**. Therefore, as compared with a case where the lead wire **131** is routed radially outward of the bearing portion **12**, in the vibrating motor **10**, the lead wire **131** can be suppressed from interfering with other portions or other members, and the vibrating motor **10** can be downsized in the radial direction. Further, the manufacturing efficiency of the vibrating motor **10** is improved.

Further, as illustrated in FIG. **4**, the board **4** is arranged below the second region **122**. The board **4** expands in the radial direction. That is, the board **4** expands in a direction intersecting the center axis J. The board **4** may be a flexible printed circuit board or a rigid printed circuit board.

The bearing portion **12** has a protruding portion **12**C protruding downward from the lower surface of the second region **122**. The lower end portion of the lead wire **131** drawn out downward is wound around the protruding portion **12**C. That is, the lead wire **131** is tied to the protruding portion **12**C.

The board **4** includes a first electrode portion **41** and a second electrode portion **42**. The first electrode portion **41** and the second electrode portion **42** are electrically connected by a wiring pattern (not illustrated in FIG. **4**) inside the board **4**. At the time of manufacturing the vibrating motor **10**, an operation of attaching the board **4** to the second region **122** and electrically connecting the first electrode portion **41** and the lead wire **131** tied to the protruding portion **12**C by soldering or the like is performed. The operation may be performed automatically or manually. Therefore, the vibrating motor **10** can be manufactured with more excellent workability compared to the case of directly connecting the lead wire to the board. Further, with a mechanism of binding the lead wire **131** with the protruding portion **12**C, the reliability of the electrical connection between the lead wire and the board **4** is improved even in a case where the outer diameter of the lead wire is small. Therefore, even in a case where the outer diameter of the lead wire is small or large, the reliability of the electrical connection between the lead wire and the board is improved. Thus, the outer diameter of the lead wire can be adjusted according to the application of the vibrating motor, and the electric resistance and output characteristics of the coil **13** can be easily adjusted.

In this manner, the lower end portion of the lead wire **131** drawn out downward from the coil **13** is electrically connected to the board **4**. As a result, the routing of the lead wire **131** for electrically connecting the coil **13** and the board **4** is facilitated.

The board **4** has a plurality of notch portions **4**A recessed from the radially outer edge of the board **4** in a direction of approaching the center axis J. The bearing portion **12** has a plurality of protruding portions **12**D protruding downward from the lower surface of the second region **122**. The plurality of protruding portions **12**D are housed in the plurality of notch portions **4**A. As a result, the board **4** can be positioned.

As illustrated in FIG. **3**, the board **4** overlaps the communication hole H**1** in the vertical direction in a state where the board **4** is attached to the lower end portion **122**B. As a result, it is possible to suppress intrusion of foreign matter into the bearing portion **12**.

Next, a method of manufacturing the vibrating motor **10** will be described.

At the time of manufacturing the vibrating motor **10**, a configuration in which the housing **11**, the bearing portion **12**, and the coil **13** are integrated is assembled in advance as a first unit U**1**. On the other hand, a configuration in which the core portion **21**, the holding portion **22**, the elastic portion **3**, and the top surface portion **14** are integrated is assembled in advance as a second unit U**2**.

Then, as illustrated in FIG. **5**, the first unit U**1** is installed on a jig **20**. The jig **20** has a recess **20**A which is recessed in a columnar shape downward from the upper surface of the jig **20**, and a through-hole **20**B which penetrates from the recess **20**A to the lower surface of the jig **20**. The center axis of the recess **20**A and the center axis of the through-hole **20**B coincide with each other. The outer diameter of the recess **20**A is substantially the same as the outer diameter of the housing **11**. The outer diameter of the through-hole **20**B is smaller than the outer diameter of the recess **20**A.

When the first unit U**1** is installed in the jig **20**, the lower side of the first unit U**1** is inserted into the recess **20**A, and the bottom surface of the first unit U**1** is brought into contact with a boundary surface **20**S between the recess **20**A and the through-hole **20**B. The boundary surface **20**S is an upper surface of a portion in which a tubular portion of the jig **20** configuring the recess **20**A protrudes radially inward.

Then, a bar-shaped jig **30** is inserted into the jig **20** through the through-hole **20**B. The jig **30** is inserted upward in the order of the inside of the bearing portion **12** and the inside of the housing **11**, and is fixed to a lower surface **2**B of the movable portion **2** (core portion **21**) in the second unit U**2** outside the housing **11**. FIG. **5** illustrates this fixed state.

In a case where the jig **30** is made of a magnetic material, the jig **30** is fixed to the lower surface **2**B by bringing the jig **30** into contact with the lower surface **2**B. Further, in a case where the jig **30** is made of a non-magnetic material, the upper surface of the jig **30** and the lower surface **2**B are fixed with an instantaneous adhesive. Incidentally, the upper surface of the jig **30** and the lower surface **2**B may be fixed by another method.

After the jig **30** and the movable portion **2** are fixed, the jig **30** is pulled downward as indicated by an arrow in FIG. **5**. As a result, the second unit U**2** is pulled downward together with the jig **30**, and the core portion **21** is inserted into the housing **11** from above. When the jig **30** is continuously pulled downward, the core portion **21** is inserted into the bearing portion **12**.

At least a part of the lower surface **2**B of the movable portion **2** overlaps the communication hole H**1** in the vertical direction. Here, as illustrated in FIG. **3**, in this example embodiment, the entire lower surface **2**B of the movable portion **2** (core portion **21**) overlaps the communication hole H**1** in the vertical direction. The entire lower surface **2**B vertically overlapping the communication hole H**1** means that in a case where the radially outer edge of the communication hole H**1** is projected upward, the entire lower surface **2**B is included in the projected radially outer edge. As a result, the jig **30** can be inserted into the bearing portion **12** from the communication hole H**1**, the jig **30** can be fixed to the lower surface **2**B, and the movable portion **2** can be pulled downward by the jig **30** and arranged inside the bearing portion **12**.

When the core portion **21** is pulled into the bearing portion **12**, the holding portion **22** and the elastic portion **3** are inserted into the housing **11**, and the top surface portion **14** can be fitted into the upper end portion of the housing **11**. After the top surface portion **14** is attached to the housing **11**, the jig **30** is detached from the movable portion **2** by inclining the jig **30**. Incidentally, another method may be used to detach the jig **30** from the movable portion **2**.

As described above, the manufacturing efficiency of the vibrating motor **10** can be improved by using the jig. At this time, the movable portion **2** is arranged in the bearing portion **12**, and thus the movable portion **2** can be accurately arranged in the radial direction.

Incidentally, in a case where the housing **11** is made of a magnetic material, and the jig **30** made of a magnetic material and the movable portion **2** are connected only by a magnetic force, there is a possibility that the core portion **21** is detached from the jig **30** and adsorbed to the housing **11** by an attractive force. Therefore, in such a case, it is desirable to fix the jig **30** made of a non-magnetic material and the movable portion **2** with an instantaneous adhesive.

Incidentally, the inner diameter D**1** at the upper end of the bearing portion **12** may be larger than the inner diameter D**2** at the lower end of the bearing portion **12**. In this case, it is easy to remove the mold upward with respect to the bearing portion **12** at the time of manufacturing the bearing portion **12**. Further, when the movable portion **2** is drawn into the bearing portion **12** using a jig, the movable portion **2** is less likely to come into contact with the bearing portion **12**.

FIG. **6** is a partial longitudinal sectional view of the lower side of the vibrating motor **10** according to a modification. As illustrated in FIG. **6**, the bearing portion **12** includes the bearing cylinder portion **122**A and the lower end portion **122**B. The bearing cylinder portion **122**A is similar to that of the above-described example embodiment. The lower end portion **122**B is arranged below the bearing cylinder portion **122**A and is a separate body from the bearing cylinder portion **122**A. That is, the bearing portion **12** has the lower end portion **122**B which is arranged below the bearing cylinder portion **122**A and is a separate body from the bearing cylinder portion **122**A.

The lower end portion **122**B has the communication hole H**1**. The outer diameter of the communication hole H**1** is smaller than the inner diameter of the lower end of the bearing cylinder portion **122**A. A part of the lower surface **2**B of the movable portion **2** (core portion **21**) overlaps the communication hole H**1** in the vertical direction. When a part of the lower surface **2**B overlaps the communication hole H**1** in the vertical direction, this means that the area of the communication hole H**1** is smaller than the area of the lower surface **2**B in the direction orthogonal to the center axis J, and when the radially outer edge of the communication hole H**1** is projected upward, the inside of the radially outer edge overlaps the part of the lower surface **2**B.

Even with such a configuration, similarly to the above-described example embodiment, it is possible to insert a jig into the communication hole H**1**, fix the jig to the lower surface **2**B of the movable portion **2** in the second unit U**2**, pull the movable portion **2** by the jig, and arrange the movable portion **2** in the bearing portion **12**. That is, it is sufficient if at least a part of the lower surface **2**B of the movable portion **2** overlaps the communication hole H**1** in the vertical direction.

Since the lower end portion **122**B is a separate body, the communication hole H**1** overlapping a part of the lower surface **2**B of the movable portion **2** in the vertical direction is easily formed in the lower end portion **122**B. In particular, in a case where the inner diameter D**2** is larger than the inner diameter D**1** (FIG. **3**), when the bearing portion **12** including the lower end portion **122**B having the communication hole H**1** as described above is integrally formed with a mold, it is difficult to pull out the mold. Therefore, it is desirable that the lower end portion **122**B be a separate body.

In the configuration illustrated in FIG. **6**, the lower end portion **122**B of the bearing portion **12** has an inward extending portion **1221** extending to the radially inner side relative to the radially inner end of the bearing cylinder portion **122**A. An upper surface **1221**A of the inward extending portion **1221** is arranged so as to face a part of the lower surface **2**B of the movable portion **2** in the vertical direction. A part of the lower surface **2**B has an annular shape. As a result, the board **4** can be fixed to the lower surface region facing the upper surface **1221**A in the vertical direction with an adhesive or the like. Therefore, the board **4** can be firmly and easily fixed. Further, even in a case where a configuration in which the lower surface **22**A of the holding portion **22** and the upper surface **123**A of the third region **123** face each other in the vertical direction to restrict the downward movement of the movable portion **2** is not provided, the lower surface **2**B of the movable portion **2** can come into contact with the upper surface **1221**A, so that the downward movement of the movable portion **2** can be restricted.

FIG. **7** is a perspective view illustrating the lower end portion **122**B of the bearing portion **12** according to another modification. FIG. **7** is a view of a state in which the board **4** is detached.

As illustrated in FIG. **7**, a groove-shaped communication portion **1222** extending in the radial direction and recessed upward from the lower surface of the lower end portion **122**B is formed in the lower end portion **122**B. The communication portion **1222** allows the radially inner space and the radially outer space of the lower end portion **122**B to communicate with each other. That is, the bearing portion **12** has the communication portion **1222** for communicating the radially inner space and the radially outer space of the bearing portion **12**. As a result, in a case where the movable portion **2** vibrates up and down, the gas inside the bearing portion **12** is discharged to the outside of the bearing portion **12** through the communication portion **1222**, so that it is possible to suppress a decrease in amplitude of vibration due to compression of the gas inside the bearing portion **12**. Further, in the configuration in which the board **4** closes the lower side of the bearing portion **12** as in this example embodiment, a configuration in which the communication portion **1222** is provided is particularly useful.

Incidentally, the communication portion **1222** is not limited to the groove shape, and may be formed as, for example, a through-hole penetrating the bearing portion **12** in the radial direction.

FIG. **8** is a view schematically illustrating a touch pen **50** as an example of a target device mounted with the vibrating motor **10**. The touch pen **50** is a device which operates a device such as a smartphone or a tablet by being brought into contact with a touch panel of the device. When the touch pen **50** is mounted with the vibrating motor **10**, the touch pen **50** can be vibrated to give haptic feedback to a user. That is, the touch pen **50** is an example of a haptic device including the vibrating motor **10**. That is, the haptic device includes the vibrating motor **10**. For example, the haptic feedback can give the user a feeling as if a character or the like is written on paper or the like with the touch pen **50**. When the vibrating motor **10** is mounted in a haptic device, it is possible to realize a haptic device having the vibrating motor **10** with high manufacturing efficiency.

The target device is not limited to the touch pen, and various devices such as an aerial operation device can be mounted with the vibrating motor **10**. For example, a device such as an electronic pen, an electronic writing instrument, or a mouse may be mounted with the vibrating motor **10**, and the device may be used as an electronic device capable of inputting a stereoscopic image or a virtual reality image.

In particular, in a case where the vibrating motor **10** is mounted in a device such as a touch pen, it is necessary to reduce the size of the vibrating motor **10**, but even the vibrating motor **10** having such a small size can be easily manufactured by using the jig as described above.

The present disclosure can be used for a vibrating motor mounted in various devices such as a touch pen, for example.

Features of the above-described preferred example embodiments and the modifications thereof may be combined appropriately as long as no conflict arises.

While example embodiments of the present disclosure have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing from the scope and spirit of the present disclosure. The scope of the present disclosure, therefore, is to be determined solely by the following claims.

What is claimed is:

1. A vibrating motor comprising:
a stationary portion; and
a movable portion able to vibrate with respect to the stationary portion along a center axis extending in a vertical direction; wherein
the stationary portion includes:
a bearing portion which supports the movable portion to be able to vibrate along the center axis and has a tubular shape extending along the center axis; and
a coil which directly or indirectly opposes at least a portion of the movable portion in a radial direction;
a lower end portion of the bearing portion has a tubular shape extending along the center axis;
a communication hole which penetrates in the vertical direction and allows an outside of the bearing portion and an inside of a portion above the lower end portion of the bearing portion to communicate with each other is provided on a radially inner side of the lower end portion;
at least a portion of a lower surface of the movable portion overlaps the communication hole in the vertical direction; and
a groove-shaped communication portion extending in the radial direction and recessed upward from a lower surface of the lower end portion is defined in the lower end portion.

2. The vibrating motor according to claim **1**, further comprising:
an elastic portion that is above the movable portion; wherein
an upper end portion of the movable portion is fixed to a lower end portion of the elastic portion; and
the stationary portion includes:
a housing which houses the movable portion and the elastic portion; and
a top surface portion which is fixed to an upper end portion of the housing and fixed to an upper end portion of the elastic portion.

3. The vibrating motor according to claim **1**, wherein
an outer diameter of the movable portion, an inner diameter of the bearing portion, and an inner diameter of the lower end portion of the bearing portion configuring the communication hole are all equal or substantially equal.

4. The vibrating motor according to claim **1**, wherein
an inner diameter at an upper end of the bearing portion is larger than an inner diameter at the lower end portion of the bearing portion.

5. The vibrating motor according to claim **1**, further comprising:
a board which is below the bearing portion and expands in a direction intersecting the center axis; wherein
the board overlaps the communication hole in the vertical direction.

6. A haptic device comprising:
the vibrating motor according to claim **1**.

7. The vibrating motor according to claim **1**, wherein
the bearing portion includes a bearing cylinder portion which opposes the movable portion in the radial direction and has a tubular shape extending in the vertical direction;
the lower end portion of the bearing portion includes an inward extending portion extending to a radially inner side relative to a radially inner end of the bearing cylinder portion; and
an upper surface of the inward extending portion opposes a portion of the lower surface of the movable portion in the vertical direction.

8. The vibrating motor according to claim **7**, wherein
the bearing portion includes the lower end portion which is below the bearing cylinder portion and is a separate structure from the bearing cylinder portion.

9. The vibrating motor according to claim **1**, wherein
an inner diameter at an upper end of the bearing portion is smaller than an inner diameter at the lower end portion of the bearing portion.

10. The vibrating motor according to claim **9**, wherein
the inner diameter of the bearing portion continuously increases toward a lower side.

11. The vibrating motor according to claim **9**, wherein
the bearing portion includes:
a bearing cylinder portion which opposes the movable portion in the radial direction and has a tubular shape extending in the vertical direction; and
the lower end portion which is below the bearing cylinder portion and is a separate structure from the bearing cylinder portion;
the lower end portion of the bearing portion includes an inward extending portion extending to a radially inner side relative to a radially inner end of the bearing cylinder portion; and
an upper surface of the inward extending portion opposes a portion of the lower surface of the movable portion in the vertical direction.

* * * * *